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ABSTRACT

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by CAPT Michael C. Herb, USN, 47 pages.

Ordnance, ammunition, and explosives are essential commodities to the warfighter. History shows that effective operational ordnance logistics, supplying the warrior with the munitions they need, is imperative to combat readiness. Adherence to a robust and effective explosives safety program reduces risk of death, injury and destruction to personnel and property which in turn can significantly enhance the combat readiness of any fighting force. Equally as true, efforts to eliminate the risk associated with munitions, failure to maintain balance between safety programs and force requirements, or the reluctance to apply technological advances in explosives, will hinder effective ordnance logistics and combat readiness.

This monograph explores the history of explosives, its use in the military, and how a number of explosive incidents spawned the development and evolution of the United States Department of Defense Explosives Safety Board and the *DOD Ammunition and Explosives Safety Standards*. To examine the balance between the safety requirements of the current explosive safety program and effective operational ordnance logistics, a comparison between the existing consequence-based explosive safety criteria and a risk-based approach is explored. The question of whether the U.S. Military can ensure a safe environment for the general public while improving the effectiveness operational logistics of ordnance and ammunition is examined and answered.

The Role of Explosives Safety in Operational Logistics

MONOGRAPH
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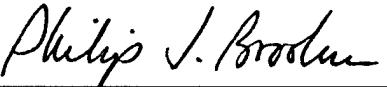
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INTRODUCTION

Ordnance and ammunition are essential commodities to any warfighter. History shows that effective operational ordnance logistics, supplying the warrior with the ammunition they need, is imperative to combat readiness. Equally true is that effective ordnance logistics must be coupled with effective explosive safety. Adherence to a robust explosives safety program reduces risk of death, injury, and destruction to personnel and property which in turn, can greatly enhance the readiness of the fighting forces. Equally as true, efforts to eliminate the risk associated with munitions, failure to maintain balance between safety programs and force requirements, or reluctance to apply technological advances in explosives, may adversely affect that readiness.

Explosive material, an inseparable component in ammunition and ordnance, is essential to military weapon system production and use. Explosives also have an inherent hazardous nature. In the past 75 years, a number of significant explosive incidents have occurred which resulted in the evolution of numerous explosives safety programs. The Department of Defense's concern for explosives safety eventually led to the establishment of the Department of Defense Explosives Safety Board and a comprehensive set of regulations, the *DOD Ammunition and Explosives Safety Standards* (*DOD 6055.9-STD*). (For the remainder of this monograph *DOD 6055.9-STD* will be referred to as the *Standard*) The *Standard* serves as the baseline for the Defense Department's Explosives Safety Program and it is the foundation for each of the service's explosives safety programs.

Explosives safety programs have had profound effects on how the military manages ammunition and explosives (A&E) and on the operational logistics that are

essential to the combat readiness of military forces. These programs enhance readiness by saving lives, preventing injury, and protecting property. However, if regulations and standards are not balanced with operational requirements, an explosives safety program might become an impediment to the logistical support and readiness the programs were established to protect. This Monograph explores the balance of differing philosophies in explosive safety by examining their impact on the military objective to enhance operational logistics and combat readiness.

Explosives safety concerns and the *DOD 6055.9-STD* have resulted in significant regulations governing the way ordnance is manufactured, handled, transported, and stored. These regulations have been constantly evolving, resulting in sweeping changes to operational ordnance logistics. Without question, this regulatory evolution has had a positive impact on safeguarding lives and property; however, safeguarding lives and property comes at a price.¹ The dollar and resource cost associated with the implementation of any large program can be significant and explosives safety is no exception. Counting the numbers of lives lost, determining the costs of damage and destruction to property, and tabulating the losses in production are routine and expected outcomes of an explosive incident and subsequent investigation. What is difficult, however, is to quantify the dollars saved in workforce productivity and ordnance operational efficiency at production, handling, and storage facilities throughout the Department of Defense as a result of an explosives safety program and standards. It is more difficult, if not impossible, to determine the cost benefits from saving human life.

Every safety program comes with a price and at some point, ideally, the cost should be balanced with benefits. Dollars and resources are expended to support

explosives safety programs but too often at a cost to operational effectiveness of logistics. A safety program, if not continuously reviewed and priorities balanced, can become so restrictive that the readiness the program protects begins to suffer. When pursuit of “zero defects” or a risk free environment takes priority over effectiveness, regulations and standards often become out of balance with operational requirements. Risk must be managed in a military that values effectiveness, especially when it equates effectiveness so closely with operational readiness.

Effective logistics are essential to combat readiness. “The understanding of the nature and degree of logistical control which command should exercise is essential to the attainment of combat effectiveness.”² To be combat effective or ready, the warrior must be sustained with the right supplies at the right time. The explosive properties of ordnance complicate logistics because of the balance between safety restrictions and readiness and thus, explosives complicate the challenge of readiness.

The use of ammunition and explosives (A&E) plays a substantial role in military history but it has not always complicated logistics and the readiness equation to the extent it has in recent years. For almost as long there have been wars, considerations and concerns dealing with the supply of the military forces that fought those wars has been paramount to planners of operations and strategy. The weapons used in battle, and their means of transport, have changed significantly with time. In the age of sword, lance, and bow, soldiers and their horses carried the weaponry. Re-supply often came from pilfering the weapons of fallen warriors. As bow and sword gave way to musket, cannons, bullets and projectiles, the logistics and sustainment of the weapons of war became increasingly more complex. With technology weapons fundamentally evolved. Weight and how to

move heavier fighting material farther and faster became the overriding challenge. At the same time, armies and navies expanded and began fighting wars farther from their homelands. “Until the year 1763, the development of the art and technology of war had been orthodox and gradual,” however the pace and impact of developments soon accelerated. “The First Industrial Revolution struck its roots in war and continued to be motivated by recurrent themes devised by inventors...”³ Inventions and innovations became, and continue to be, a significant contributor to war.

In the middle to late eighteenth century, the Industrial Revolution spawned developments in steam shipping, railroads, and eventually power vehicles that brought dramatic change to the problems associated with transportation of heavier weapons and munitions. Technological advances of this century also allowed for rapid improvements in both the range and the lethality of weapons. The advent of bullets, grenades, and high explosives in projectiles and bombs however, created a new problem and a different threat. How to safely manufacture, stow, and transport these improved munitions soon emerged as a concern. There is little doubt that the use of explosives greatly enhanced the effectiveness of weaponry but this advancement brought with it greater hazard and increased risk to ordnance logistics.

In 1926, an explosion at the Naval Ammunition Depot, Lake Denmark, New Jersey, killed 21 people and resulted in a monetary loss of \$46 million. This incident compelled the Seventieth Congress to direct the establishment of a board of U.S. Officers that would provide oversight for explosives safety and ultimately mature into the Department of Defense Explosive Safety Board (DDESB).⁴ On 18 July 1944, the worst explosive disaster within the continental United States again generated substantial

scrutiny of explosive operations. In this catastrophic explosion on the Sacramento River at Port Chicago (now Naval Weapons Station, Concord, CA), 320 men were killed, a pier and two ships were destroyed, and the base and the neighboring civilian community were badly damaged. While the exact cause of the Port Chicago explosion was never determined, the incident investigation, and subsequent inquiries in connection with the mutiny courts martial that followed, had profound effects on ordnance logistics for the future.⁵

As munitions evolved and a number of explosive mishaps occurred, an explosives safety philosophy that is deterministic and consequence-based began to emerge. This philosophy assumed that explosive mishaps would occur and therefore focused on keeping personnel as far away as possible. Explosive safety quantity distance (ESQD) arcs were instituted. These ESQD arcs are at the core of current explosive safety standards and focus on minimizing exposure of personnel and facilities to ordnance storage and handling. The distances of these safety arcs are determined by the amount of explosive at any location and the area that would be affected in the event of a detonation.⁶

Improvements to munitions and the procedures used to handle them evolved because of explosive incidents like Lake Denmark and Port Chicago; however, these improved safety procedures did not eliminate explosive mishaps. At the Bien Hoa Air Base, South Vietnam in 1965, a fuse functioned inadvertently and detonated a bomb causing 133 casualties and the destruction of fourteen aircraft. In 1990, during Desert Shield, a similar mishap occurred at the Al Kharj Air Base. Fortunately the original aircraft parking plan was modified by the weapons safety officer to allow for greater distances between loaded aircraft, which minimized the resulting damage.⁷

Establishment of explosive safety standards and quantity distance criteria has not eliminated explosive risk but it has reduced the risk and enhanced personnel safety. Additionally, technology in munitions has produced explosives, fuses, and detonating devices that have significantly reduced the sensitivity of munitions.⁸ As safety requirements become more stringent and standards more rigid, the emerging issue is whether the pursuit of risk reduction adversely affects operational readiness by degrading the responsiveness and flexibility of combat support and logistics in the area of ammunition and ordnance.

Consideration of the following hypothetical example illustrates this dilemma of risk reduction versus readiness. The U.S. uses a remote island as a logistic support base for fuel, stores, and small amounts of ammunition. This support area, which includes a harbor, port, and small base, has an approved explosive safety site plan. For reasons of U.S. National interests and increasing regional threats, the U.S. Military wants to use this base for forward pre-positioning (PREPO) support and specifically, locating a number of PREPO type cargo ships, including an ammunition ship, in the island harbor. According to the current safety criteria of the *Standard*, the fact the ammunition is stored on a ship and not being handled, the small number of exposed personnel, or relatively slight possibility of an explosive incident on this fictitious island makes no difference. Regardless of how remote the possibility of a detonation, the explosive safety quantity distance (ESQD) arcs are the same, determined only by the amount of explosives. Unfortunately the large quantities of ammunition on a PREPO ship would far exceed the maximum limits of the harbors current site plan. Furthermore, the support infrastructure and workforce could not accommodate expanding its limits. The *Standard* assumes an

incident will occur. The “consequence based” *Standard* does not allow for informed and safe decisions based on prudent risk assessment. The *Standard* does make provisions for waivers; however, this is an elaborate documentation and review process, requiring multiple endorsements and often takes six to eighteen months for approval.

While the above scenario is a hypothetical one, it is representative of explosives storage and handling site planning dilemmas faced regularly within the Services. This monograph examines the history of explosives safety and its importance to ordnance logistics. It then explores how the evolution of explosives safety programs, explosives technology, and the development of less sensitive munitions has affected ordnance logistics and readiness. After establishing this background, the dilemma of what direction the Department of Defense should take in managing ordnance logistics is examined by exploring two explosive safety philosophies. The current “consequence-based” deterministic type of explosive safety criteria is compared to a “risk-based” risk management type approach. The criterion for the comparisons of these two explosive safety philosophies is their relative impacts on operational requirements of the US Military.

DEFINITIONS AND BACKGROUND

A number of terms used throughout this monograph, must be defined to properly understand explosives safety, ordnance logistics and how they both relate to combat readiness. Terms used less frequently or only once are defined as they are used.

Explosives is a term that is equally applicable in military and non-military settings. According to the *Riverside Webster's II Dictionary*, an explosive is substance or chemical preparation that explodes. To explode is to release energy (primarily heat and rapidly expanding gas) violently and suddenly. Explosives is a term for a group of items that are explosive by nature or by design. **Explosives Safety**, as defined within the Department of Defense, is the condition where operational capability, personnel, property, and the environment are protected from the unacceptable effects of an ammunition or explosives mishap.⁹

Ordnance and **ammunition** are often use synonymously within the military as well as outside. Ordnance, the more all encompassing term, is defined as explosives, chemicals, pyrotechnics, and similar items. Included in the ordnance category are bombs, guns, ammunition of all kinds, flares, etc. Ammunition or munitions, a subset of ordnance, are devices charged with explosives, propellants, pyrotechnics, initiating compositions, nuclear, biological or chemical material for use in military operations. This monograph will only deal with **conventional** explosives and ordnance, which are those explosives and ordnance that are not nuclear, chemical, or biological.¹⁰

In the most comprehensive sense, **logistics** is “the science of planning and carrying out the movement and maintenance of forces...those aspects of military operations which deal with design and development, acquisition, storage, movement,

distribution, maintenance, evacuation, and disposition of material.”¹¹ A more narrow definition of logistics deals only with the storage, movement, and distribution of material to sustain operating forces. In this monograph, logistics is confined to this more narrow context. The term **Ordnance Logistics** thus refers to the storage, movement, and distribution of ordnance. When consideration is given to the readiness of the forces, the ordnance must be of the correct type, condition, quantity, and delivered to the place where needed. A simple definition used within logistics and ordnance wargames throughout the past three years is “to deliver the Right ordnance, in the Right quantity, and the right condition, to the Right location, at the Right time.”¹²

Two terms are central to any discussion concerning explosive safety criteria and the *Standards*. A **Potential explosion site (PES)** is the location of a quantity of explosive that will create a blast, fragment, thermal, or debris hazard in the event of an accidental explosion of it or its contents. An **Exposed site (ES)** is a location exposed to the potential hazardous effects from an explosion at a potential explosive site or PES. The relationship established from these two definitions is that the distance to the nearest exposed site or ES, determines the amount or quantity of explosives permitted at a potential explosion site, PES. The actual relationship between the quantity of explosive material, or **NEW** (net explosive weight) and separation distance necessary for protection is expressed as **QD**, which refers to a distance from any given quantity of explosives.¹³

The evolution of explosives safety and its impact on the military must be considered to properly understand the balance between risk associated with the operational use of explosives and ammunition, and operational effectiveness and combat readiness. The history of explosives and the background that brought about current

explosives safety standards within the Department of Defense dates back to around 500 AD. The exact origins of explosives or the first gunpowder are unknown. Before the seventh century there is some evidence that the elements of nitrate, charcoal, and sulfur were used in various proportions for a variety of mystical events and entertainment. As with many other discoveries and inventions, it is only a matter of time before a military application is developed. “The first reference to the use of Blackpowder for practical purposes is in the military field where Marcus Greacus in the year 700 AD describes its use in crude rockets and thunder flashes for demoralising the enemy.”¹⁴ Throughout the next several hundred years, the military dominated the development and use of explosives. Between the 13th and 15th centuries an industry began to grow in support of their military applications. It was not until the 17th century that non-military applications for explosives were recognized.¹⁵

As the application of explosives became more frequent and varied, so did the issues associated with its safe use. The initial concerns with the use of explosives centered on how to safely detonate the powder without being in the immediate blast area. With the amount powder used in the flintlock weapons and the confined explosions associated with the cannons of the 18th century, this was not a huge concern. For the larger and more open detonations needed for mining, safe distance was a greater concern. A number of crude ideas were developed and tested with varying degrees of success. A significant breakthrough came in 1804 when William Bickford of Cornwall invented the basic safety fuse. Baron Chastel of Austria then refined the idea by using an electric spark to ignite the fuse.¹⁶ A year later in 1805, an English parson, Alexander Forsythe produced a tiny mercury percussion cap that paved the way for breech loading, cartridge

type firearms and artillery. This development had a significant impact on ordnance logistics for decades to come. Single rounds of ammunition would soon consist of propellant, explosive charge, fuses, and detonating devices. Complete munitions eased storage and movement but as history soon showed, these innovations created a hazard that had devastating potential.¹⁷

The use of technology resulted in significant safety improvements in the detonation of explosives but concerns associated with its manufacture and storage also emerged. The risks associated with detonating explosives were for the most part, the concern of those immediately involved in its use; however, the risks inherent to the manufacture and storage of explosives often involved the general population. These hazards to the public brought about the early forms of explosive safety documentation and regulation. In the late 1770s, the Continental Congress established the Committee of Safety of Philadelphia that carried out the construction and oversight of numerous public powder mills. This action was a result of accidents in which a number of these mills “blew up.”¹⁸ During the same time period England was experiencing similar concerns with safety. An excerpt from a 1776 instruction from the Waltham Abbey gunpowder mill stated, “Everybody is charged with the utmost caution and prudence in the handling of the powder by due observance and remembrance of what hath been deemed to that end.” Those persons who did not comply with these instructions were not only dismissed but were “put under arrest and in accordance with the verdict be sentenced for the crime committed.”¹⁹

As the use of explosives grew and diversified in mining and construction, as well as in the military, so did the hazards and the subsequent explosives safety awareness.

Throughout the 1800s explosive safety regulation and legislation evolved and matured but lacked consolidation. A key source of early United States law came from British legislation. Most influential was the Explosive Act of 1875 that originated from the Gunpowder Acts of 1860 and 1862. So comprehensive was this legislation that it was not replaced in its entirety until the promulgation of the Health and Safety at Work Act 1974 (HSWA).²⁰

Throughout the 19th century the United States explosives safety criteria centered on storage, handling, and transportation but it remained fractured and lacking consolidation. In 1906, *Notes on Military Explosives* written by Major Erasmus M. Weaver, U.S. Army Artillery Corps, was published. This comprehensive work was one of the earliest to compile data and associated restrictions in all areas of explosives operations and became an authoritative source for the military.

In 1926 a watershed event occurred that had two significant and lasting impacts on the United States military. A series of explosions at the Naval Ammunition Depot, Lake Denmark, New Jersey, virtually destroyed the depot, caused heavy damage to the nearby surrounding communities, killed 21 people, seriously injured 51 others, and resulted in a monetary loss of \$46 million. The Lake Denmark accident caused such a public uproar that it resulted in a full-scale congressional investigation. The results of this investigation became record as House Document 199 that summarized the ammunition storage and handling conditions at the time in the United States.²¹

The first and most obvious impact of this disaster was the birth of what is today the Department of Defense Explosives Safety Board. The second outcome from the incident was less apparent. The destruction at the ammunition depot was obvious but

only those who understood the complexity of ordnance logistics could see the potentially grave impact such an incident could have on combat readiness. Thus, the Lake Denmark explosion foreshadowed the linkage between explosive safety, operational logistics, and readiness.

LOGISTICS, EXPLOSIVE SAFETY, AND COMBAT READINESS

A robust transportation system, good inventory accuracy, asset visibility, and effective stockpile management are key and essential elements of a complete and interdependent operational logistics formula. Remove any of these elements from the logistics equation and effectiveness of combat support greatly diminishes. Furthermore, the major consequence from a reduction in combat support effectiveness is ultimately degradation in combat readiness. The movement and storage of ordnance requires the unique element of a comprehensive set of safety criteria that other commodities do not have to contend with, which greatly complicates the logistics requirements. Explosives safety is a key and essential element of ordnance logistics and thus, there exists a critical linkage between logistics, explosives safety, and combat readiness.

The critical linkage of effective logistics to combat readiness of any armed force is documented throughout history. Anyone questioning the essential role that logistics plays in winning wars need only read Henry E. Eccles' classic work *Logistics in the National Defense*. Operational logistic support sets the conditions for victory whether on the battlefield, in the air, or at sea. According to Eccles, "Logistics is merely a convenient term used to encompass the problem of controlling all the 'means of war' as appropriate at the various levels of command." He goes on to say, "In all war situations, the actions and decisions of command, whatever the level, are based upon a blend of strategical, logistical, and tactical considerations."²² Because of this essential blend of elements, logistics can not be separated from the planning or execution of any military action. The vast importance of logistics was expressed similarly in 1952 by the Secretary of the Navy, Dan A. Kimball. In the conclusions from *Naval Doctrine Publication 4, Naval*

Logistics, Secretary Kimball is quoted: “Victory is won or lost in battle, but all military history shows that adequate logistic support is essential to the winning of battles.”

The inseparable role that logistics plays in combat readiness may change with time, but it will not diminish. Advances in technology and warfighting techniques have changed the face of battle and modernized support capabilities but operational logistics remain absolutely critical. *Joint Vision 2010*, drafted in 1996, is evidence that the Joint Chief of Staff understood the continuing importance of logistics. In *JV 2010*, Dominate Maneuver, Precision Engagement, Focused Logistics, and Full-Dimensional Protection are institutionalized as the four operational concepts that are essential for achieving combat readiness and the “Full Spectrum Dominance” necessary to assure victory in future armed conflict.²³ Logistics can not be excluded from the vision of the future anymore than it can be written out of history or eliminated from current operational planning.

Logistics is a broad term and consists of a number of elements. The logistics functions outlined in *Joint Pub 4-0*, are supply systems, maintenance, transportation, general engineering, and health services. Of the numerous logistic functional areas, supply and transportation are most traditionally referred to when operational logistics is discussed. To Admiral Arleigh Burke, logistics logically come by sea. “No matter who carries the load in any fight – soldiers, sailors, airmen or marines – they need to be supported and supplied from the sea.”²⁴ Whether if by sea or air, transporting supplies to the fight is the centerpiece of logistics and of all the supplies and commodities that a fighting force requires, ordnance is arguably one of the most critical.

Valid arguments can be made for why many of the commodities needed to sustain a force are so essential. Fuel, food, spare parts and ammunition are without doubt, staples that no army, navy or air force can do without. Of these, fuel and ammunition can have the most dramatic affect. Armies have been known to cannibalize for spare parts and forage for food but when the gas and bullets are gone, a commander can only hope that the enemy has run out as well. Only speculation can guess how much earlier the German Army would have surrendered during World War II if the offensives by Generals Bradley and Patton had not been halted by a lack of gasoline and ammunition. "For the next two months supply limitations were to dominate operational plans and allies were now to learn the real meaning of the tyranny of logistics."²⁵

Another way to consider the predominant role that ordnance and ammunition play in the logistics equation is to compare it to other commodities by weight alone. Again looking at World War II records, 55 pounds of supply support was required each day for each man. Fifty percent of this daily consumption was ammunition. An examination of the required quantities of supplies that were estimated for an armor division during Desert Storm planning confirms this as well. Within the four areas of unit posture, offensive, defensive, pursuit, and reserve, only pursuit required less tons of ammunition than among the other three categories of spares, food, and fuel. In the offensive and defensive postures, ammunition requirements were 3 to 4 times that of even fuel as measured in tons per day.²⁶

Combat readiness depends on effective logistics, and ordnance is the key commodity that operational logistics must deliver. The difficulty is that explosives, bombs, bullets, rockets, and missiles, create a number of unique and extremely difficult

challenges for the logistian. The explosive properties of military ordnance make it necessary for restrictions in logistical functions like handling and storage that are unlike all other commodities used by the military. This situation brings about an ironic dilemma. The commodity that is most crucial to combat readiness is also governed by the most stringent safety standards for its storage, transportation, and distribution. The regulated standards of ordnance logistics complicate and often inhibit effective ordnance logistics and can actually slow the flow of munitions to the warfighter. This dilemma creates the inseparable link between explosive safety and combat readiness. Maintaining strict safety criteria is costly and at times inefficient; however, disregarding explosives safety *Standards* can have devastating consequences during war as well as peace.

On 11 July 1991, at the close of Operation Desert Storm a small fire occurred during maintenance on a M992, field artillery ammunition support vehicle (FAASV), at Camp Doha, Kuwait. This fire would have caused less than \$200,000 damage but because the vehicle was loaded with ammunition along with a number of other vehicles parked in its vicinity, the results were far more disastrous. In all, 58 soldiers were injured, 181 vehicles were destroyed or damaged, and a total of \$40 million worth of supplies, property, and equipment was lost. The subsequent investigation revealed that a number of Army explosive safety separation and storage violations had occurred. The small fire in one vehicle nearly decimated a battalion-size unit.²⁷ Combat readiness was degraded.

During the Vietnam conflict the majority of the expended munitions came from various inland storage facilities; were loaded on ships; and were then transported across the Pacific Ocean and delivered directly to ports in South Vietnam as well as secondary

sites such as Guam and Subic Bay, Philippines. A large portion of this ordnance was handled and loaded at Naval Weapons Station, Concord, CA., formally U.S. Naval Magazine, Port Chicago. Throughout the peak years of fighting a total of 1.2 million short tons of ordnance per year passed across the piers at Concord on its way to the Southeast Asian Theater. During this six to seven years, Concord was operating at three piers with a combined net explosive weight (NEW) capacity in excess of 20 million pounds at any one time.²⁸ It is difficult to estimate what the impact would have been if an explosion occurred similar to the Port Chicago explosion some 25 years earlier. Considering that the Port Chicago explosion involved 3.5 million pounds NEW compared to the 10 to 15 million pounds handled routinely during the Vietnam War, there is little question that the resulting destruction to the facilities at Concord would have been devastating. Because of NEW limitations, no other port facility on the West Coast could have handled that throughput. If Concord were lost, the logistical flow of ammunition to Southeast Asia would have been crippled resulting in significant degradation to the combat readiness of American Forces in Vietnam.²⁹

Similar circumstances could have caused significant readiness problems during Desert Storm. As during the Vietnam War Naval Weapons Station Concord was once again a critical transshipment point in support of ordnance logistics to Persian Gulf. Although the conflict was obviously shorter in duration and the transshipment points were more evenly balanced; Concord still pushed about 300,000 tons of ordnance to the theater in a six to seven month period. Loss of Naval Weapons Station Concord from an explosive accident would not have crippled the war effort but it would have certainly degraded combat readiness.³⁰

If combat readiness is enhanced by effective ordnance logistics, and both of these are linked to explosive safety, then a key to ensuring and maintaining combat readiness centers on incorporating the most effective explosive safety program. Explosive safety has clearly evolved into an exceptionally effective program that has substantially enhanced combat readiness. However, a different approach may potentially yield even better results. The remainder of this monograph examines and compares the two primary explosive safety philosophies and their potential impacts on combat readiness for the military.

CONSEQUENCE BASED EXPLOSIVES SAFETY STANDARDS

The catastrophic explosion that occurred at the Lake Denmark Ammunition Depot in 1926, was the impetus for Congress establishing a specific board of U.S. Military Officers to oversee the storage and handling of ammunition within the Armed Services. This first Board, established by the 70th Congress on 22 December 1927, eventually became the Department of Defense Explosives Safety Board that exists today. (No official designation was given to the first board until 1945 when it was titled The Army-Navy Ammunition Storage Board). Throughout this same time period a number of events and incidents caused the parallel evolution of the explosives safety criteria or standards these early Boards adopted or developed. Also evolving was the consequence or deterministic philosophy on which today's *Standard* is based.

The primary task set before the Board was to make an assessment of explosives safety conditions and to standardize requirements for the services. An excerpt from a 22 December 1927, Congressional Action reads, "The Secretary of War and the Secretary of the Navy, through a joint board composed of officers appointed by them, shall make a survey of the points of storage of supplies of ammunition and components thereof for use of the Army and Navy, with special reference to the location of such ammunition and components as are in such proximity to populous communities and industrial areas as to constitute a menace to life and property."³¹ A follow on Act on 29 May 1928 (45 Stat. 928), resulted in the Board adopting the State of New Jersey Law, Chapter 87, of 1925 as the U.S. Military's first explosives safety standard. The New Jersey standards were chosen because they were considered to be the most stringent in the U.S. at that time. These standards incorporated the American Table of Distances and were published in the

Army Ordnance Safety Manual, O.O. Form 7224, and the Bureau of Ordnance Pamphlet 5, "Ammunition Ashore."³² The adoption of these standards by the Board marked the beginning of the first comprehensive U.S. Military explosives safety program, which was framed around the assumption that an incident or explosion would take place. Therefore, the way to protect the public was to limit or eliminate exposure to the explosions effects. This philosophy is deterministic or consequence based.

During the period between World War I and the start of World War II, the Board's work was on a part-time basis. The U.S. Military maintained the New Jersey State explosives safety laws but the Service's requirements began to expand which prompted the Board to consider an increasing number of military unique modifications and additions into the Service's respective ordnance safety publications. The Board's membership was restricted to two Army and two Navy Officers who performed their board duties collaterally to their regularly assigned responsibilities. Between 1935 and 1942, the board only met two times per year. As World War II accelerated, so did the operations of the Board. By the end of the War, the Board was working full time due to the large number of emerging explosives safety issues and several major explosive incidents.³³

One such incident was the explosion at the U.S. Naval Magazine, Port Chicago, CA, on 17 July 1944. In one of the worst afloat explosive accidents in history, two Ammunition Liberty Ships, the *Quinault Victory* and the *E.A. Bryan* exploded with a total of 3,500,000 pounds NEW. Both ships and the pier were destroyed, and 320 sailors were lost. Just four months after the Port Chicago disaster, another ammunition ship at an

advance base in the Pacific exploded during offload resulting in the loss of the ship and 382 men.³⁴

These operational port explosive incidents helped make it apparent that explosives safety concerns must be extended to the waterfront. These same accidents also demonstrated how logistics capability and readiness are tremendously vulnerable to the risks inherent to handling of large quantities of ordnance at key throughput points. The potential impact of the major losses associated with these types of disasters at primary ordnance logistics ports was discussed in section III, Logistics, Explosives Safety, and Combat Readiness. Partially because of these emerging concerns, a number of fundamental changes in Board philosophy took place during World War II and the years immediately following.

Up until World War II, the explosive standards used by the military dealt almost exclusively with manufacture, storage, and inland transportation. In 1943, the Board moved away from New Jersey State Law as the baseline for the standards and began developing its own criteria for the services. Between the years of 1945 and 1946 the Board actually conducted a series of model and full-scale explosive tests and recommended a number of changes to existing safety tables. An additional major change came in 1945 when the Board began to expand the standards to include piers and wharf areas and operations. In 1947, the Defense Department was established by the National Security Act of that year and at the same time the Board was given the official name of the Armed Forces Explosives Safety Board with representation of the Departments of the Army, Navy, and Air Force.³⁵ A final significant action came from an October 27, 1949, letter from the U.S. Attorney General, J. Howard McGrath. This letter and its

interpretation of the 1927 Congressional action became the basis for Section 172 of Title X, United States Code, under which the Board is granted its authority and the *Standards* are now binding for all Services.³⁶

Despite the broadening of Board's responsibilities and the scope of the *Standard*, focus remained on the non-operational aspects of logistic for ordnance and ammunitions. The *Standard* was not uniformly applied to ordnance logistics within the operational theater. Once again the wartime environment provided catalyst for change. The Vietnam War and particularly the bombing campaign demanded huge quantities of ordnance to be shipped to Southeast Asia. Fortunately no major explosive incident occurred at the primary shipment points in the United States; however, there were problems within the theater of operations. One of the lessons learned, documented in the Department of the Army's *Vietnam Studies*, stated "Loss of several Ammunition Supply Points (ASPs) to fire and enemy action justifies the need to find a better method of storing ammunition in a combat zone."³⁷ The essential responsibility of the Board is not to prevent explosive incidents but rather to limit the effects of an explosion should it occur. Incidents will occur during war; therefore the operational theater was the next logical step for the Board and the *Standard*. Shortly after the United States pulled out of Vietnam, the Board published a new chapter to the *Standard*, Theater of Operations Quantity-Distance, currently Chapter 10.

The *Standards* in use today are comprehensive and under constant review by the users as well as Board members. In short, they establish "uniform safety standards applicable to ammunition and explosives, to associated personnel and property, and to unrelated personnel and property exposed to the potential damaging effects of an accident

involving ammunition and explosives during their development, manufacturing, testing, transportation, handling, storage, maintenance, demilitarization, and disposal.”³⁸ Each Service has established their individually tailored explosives safety doctrine; however, they are all based on the DDESB *Standard*.³⁹

The requirements of the current *Standard* are a constant equation between two variables. The first variable describes **effects of an explosion**, and the second, more constant variable defines the **permissible exposures** for personnel. To examine the **effects** resulting from an explosion, two factors must be considered. The first of these factors is how hazardous is the material and how much of it is present. The *Standard* classifies explosives by “Hazard Division.” The *Standard* dictates the use of a system of classification devised by the United Nations Organization (UNO) as well as the appropriate Department of Transportation (DOT) class and marking in accordance with 49 Code of Federal Regulations 173. Of the nine hazard classes, only Class 1 and to a very small degree Class 6 (example of Class 6 would be riot control agents without explosives contained) are defined by the *Standard* as ammunition and explosives. Hazard classes are further broken down into divisions that indicate the character and predominance of the associated hazard. The *Standard* primarily deals with Class 1 and Divisions 1 through 6. Hazard 1 Division 1 or “Hazard Division 1.1” is mass-detonating and the most hazardous. The classifications progressively become less hazardous to Hazard Division 1.6, which is extremely insensitive ammunition.⁴⁰

In addition to knowing the type of hazard, the amount of explosive material that would detonate or burn is the other critical piece of information. This amount or quantity is the weight of the actual explosive substance in the ordnance item or munitions. This

quantity is the NEW or Net Explosive Weight. NEW is a generally expressed in pounds. Short Tons are the measurement units used for transportation and shipment. This weight includes all components of the ordnance item, i.e. NEW plus projectile and casing, plus fusing and guidance, etc.

The second factor to consider when examining the effects of an explosion is the various outputs from the explosive event. These outputs are blast pressure, primary and secondary fragments, and thermal and chemical hazards. Each of these can be measured by testing and then predicted for the different hazard types and amount of explosive material.

Knowing or being able to predict the effects from an explosive incident, based on the type and amount of explosive material , allows for the determination of **permissible exposure** for personnel. These exposures are figured for the maximums that humans can tolerate without significant harm. For example, blast overpressure is calculated for occurrence of eardrum rupture, lung rupture, and mortality; fragments are considered hazardous if they have an impact energy of 58 ft-lbs or greater; and so on. The consolidated information from the effects of explosions and the permissible exposure for personnel allows for the determination of safe distance arcs for any given quantity and type of explosive.⁴¹

The philosophy behind the *DOD Ammunition and Explosives Safety Standards* is to predict what the effects will be when an explosion occurs and ensure that loss of life and property is prevented. The *Standard* does not address incident prevention. This is the responsibility of the individual Services and is part of their safety programs. The *Standard* does not consider what the probabilities are that an explosion will or will not

take place; it simply assumes that an incident will eventually take place and therefore plans for those consequences. This philosophy is what makes the *Standard* deterministic or consequence based.

There is no question that the *Standard* is an extremely comprehensive set of regulations that contain effective measures to prevent death, injury, and destruction. The catastrophic fire and resulting explosions that nearly destroyed an entire battalion-sized Army unit at Camp Doha in Kuwait, near the end of Desert Storm, is a prime example. Simply put, had the provisions of proper stowage and separation of explosive and vehicles as delineated in the *Standard* been in place, there would have most likely been few if any injuries and only one instead of 181 vehicles destroyed or damaged.⁴²

A more recent example of the *Standard*'s effectiveness was dramatically demonstrated at the Naval Surface Warfare Center in Indian Head, Maryland. At 2225 on 01 August 1994, magazine 518, loaded with a total of 98,131 pounds NEW, sustained a sequence of fire and explosions resulting in the loss of the entire magazine. The cause of the initiating fire was most likely an auto-ignition of one of the propellants stored in the magazine. The post incident investigation showed a number of problems in Navy and local command operations and management procedures that contributed to the fire and subsequent explosion. From the DOD perspective, the magazine area was properly sited in accordance with the *Standard*. A positive outcome of the Indian Head incident was that the siting criteria of the *Standard* proved effective. Explosives in the adjacent magazines were unaffected by the blast; there was only minor damage to surrounding property; and there were no injuries or loss of life.⁴³

The *Standard* has proven effective throughout its history, however, not without an associated cost in dollars, resources and in some instances, efficiency. Establishing and maintaining large Quantity Distance arcs is not a problem if you have sufficient real estate. Additionally, there have been significant technical advances and improvements in ammunition and explosives that have made them safer to handle and store. The question raised is whether or not the U.S. Military must continue to base its explosive regulations on consequence or is there another option for maintaining explosives safety while enhancing ordnance logistics and combat readiness.

RISK BASED EXPLOSIVE SAFETY

The consequence based, *DOD Ammunition and Explosives Safety Standards* are developed with the assumption that an explosive event will occur and therefore the requirements of those standards seek to prevent death and injury to personnel, and destruction of property resulting from the effects of that event. In contrast, the risk based philosophy approaches explosives safety from a different perspective. Risk Based Explosive Safety (RBES) not only recognizes the possibility of an occurrence and the potential devastation that can be caused by a major explosion, but it also takes into account a number of factors that the current *Standard* does not.

The hazards associated with an explosion do not change regardless of how you prepare for it. The type and amount of explosive material and the exposure of personnel remain the primary factors for developing a safety program. Over-pressure, fragmentation, and thermal energy still exist regardless of how an explosives safety program is approached. What differs with RBES is that technology, probability of an incident occurring, and operational variables are taken into account when determining safe distances and exposures.⁴⁴ Why the differences occur is a function of the perspective from which RBES is approached. To understand the difference in the two approaches requires an understanding of the philosophy behind risk management.

The U.S. Army opens Chapter One of its Risk Management Field Manual, *FM 100-14*, with this quote from Sun Tzu: “Sizing up opponents to determine victory, assessing dangers and distances is the proper course of action for military leaders.” It goes on to define risk management as “the process of identifying, assessing, and controlling risks arising from operational factors and making decisions that balance risk

costs with mission benefits.”⁴⁵ The Jason Associates Corporation, who specializes in risk based and environmental consultation, offers a more specific definition in its 1998 Strategic Vision. “Risk management consists of an integrated set of programmatic control, monitoring activities, and information assimilation procedures that function to reduce risk and achieve levels of performance inherent in an operation.” The characterization of risk comes from a combination of the probability that an incident will occur and the severity of the potential loss as a result of the hazard.

The concept of applying risk management to explosives safety was not an idea originated in the United States. In fact, the Swiss began working with a risk analysis approach in the 1960s after circumstances, environment, and resources pointed to a need for change. A series of four catastrophic ammunition storage explosions that occurred in the late 1940s killed 19 people and resulted in the Swiss establishing their own Ammunition Storage Board made up of both military and civilian personnel. This board worked out a new set of strict safety regulations based on the widely accepted principles of safety distances (ESQD) based on type and quantity of explosive. It was not long however before “these regulations showed to be too inflexible to respond properly to the new problems evolving: Military readiness called for additional storage space closer to the populated areas. At the same time, a great number of residential, public and industrial buildings, and roads were built closer and closer to existing storage. And finally, the financial funds were limited as always and anywhere.” The Swiss were studying risk management in the late 1960s and began conducting experimental risk analysis for selected groups of underground magazines in 1970.⁴⁶

The Swiss safety concept consists of an assessment of two components. The first, **risk analysis** is the objective analysis of what can actually happen. This is a technical analysis based on known quantities like the amount (NEW) of explosive material, type or classification of explosive (high explosive, pyro, fragmenting, etc) and exposure to public (in open, stowed in magazine, etc). These are the same factors that are combined and computed to determine the U.S. Military's Explosives Safety Quantity Distance arcs (ESQD). Consequence based explosives safety philosophy (the *Standard*) ends assessment at this point, with risk analysis. The second component of the Swiss safety assessment concept is **risk appraisal**. Risk appraisal is a subjective examination of the social values or judgments surrounding a given circumstance. Risk appraisal asks the question, what is acceptable? The collection of factors such as, the number of individuals exposed and for how long, the actual probability of an incident and cost benefit analysis can all be considered for optimizing effectiveness.⁴⁷

Discussing cost benefit in the same context as explosive safety appears, to the outside observer, an attempt to measure safety in terms of cost or suggest that safety should be limited if too expensive. Neither perception is true but, in fact, by conducting thorough assessment and risk appraisal, options to safety related dilemmas can be discovered that are as safe, or safer, and less costly than the alternative. The Swiss found this to be the case in the early 70s when they were faced with the problem of explosive laden trucks transiting between an ammunition factory and storage area. Objective risk analysis alone indicated that an intersection at the main road crossing was the problem and building an underpass below the main intersection was the answer. After an assessment that included a risk appraisal, they discovered that the main intersection was

only 40 percent of the total collective risk and therefore they considered a broader range and greater number of safety measures. The assessment showed that the greatest safety benefit came from combined improvements in vehicle markings, better traffic lights and fire fighting upgrades. The Ministers of Defence and State decided on the combined improvements that cost a total of one million in Swiss Francs. The underpass would have cost 7 million Francs.⁴⁸ Through a complete risk-based assessment the Swiss achieved an acceptable safety standard at significantly less cost.

The U.S. Military's DOD Ammunition and Explosives Safety Standards, DOD 6055.9-STD, is without question a thorough and extremely effective set of safety criteria. The explosives safety record during the past fifty years is evidence of the *Standard's* value. A number of factors however have raised the question as to whether or not DDESB should not augment or replace the consequence-based *Standard* and pursue a risk-based philosophy.

One factor is that base closings resulting from the military downsizing of the 1990s have included a number of munitions storage facilities. These closings have occurred at a much faster pace than the current inventory of munitions have been expended or disposed of resulting in the need to increase storage and an increase in the mix of inventory at remaining facilities. Ironically, this increased load requirement at the existing storage areas has, in some instances, taken capacities to the limits set by the *Standard*. When this occurs, the only option is to expand storage or apply for a waiver or exemption to the *Standard*.

A second reason the U.S. Military is moving toward risk-based explosives safety is that waivers and exemptions are increasingly being used to authorize explosives

storage and operations that are in violation of the *Standard*. DOD 6055.9STD contains provisions and procedures for application of waivers and exemptions; however, the process is tightly controlled and the Secretary of Defense has initiated an effort to actually reduce the number of waivers and exemptions that are currently in existence within the Department of Defense.⁴⁹

Another key argument for pursuing risk-based explosives safety is that military ordnance is inherently less hazardous than it was fifty years ago and there is an ongoing program to continue making it safer. The Navy first implemented an Inensitive Munitions Program designed to develop and incorporate the least sensitive energetic materials for its ordnance. Explosives and munitions are actually tested against fast and slow burning, bullet and fragmentation impact, and sympathetic detonation. All Services currently have an Inensitive Munitions program and all munitions also undergo various drop tests.⁵⁰ The current *Standard* does not recognize these technological improvements which significantly reduce the probability of an explosive incident.

For the combination of these and other factors, in August of 1997, the Department of Defense Explosives Safety Board voted and established a Risk-Based Explosives Safety Criteria Team (RBESCT) to study the feasibility and desirability of the Department of Defense adopting a risk-based philosophy. The team is made up of participants from all Services and included international participants from the United Kingdom, Australia, and Switzerland. The specific objectives of the team is to determine the applicability for the risk-based approach, establish a methodology for evaluation and decision making, develop a computerized model, and finally, recommend a set of criteria for use in decision making.

Fundamentally, the intent of Risk-Based Explosive Safety Criteria is to establish the risk permitted in the hazardous explosive environment. The criteria are based on probability of event, weight and type of explosive, type of operation, type of population exposed, and probability of fatality. Population is broken into four categories: individual worker, group worker, individual public, and group public. The population type is a factor that affects the amount of risk.

The model or assessment method is a product of three components that combine to estimate the annual **expected fatalities** and the **maximum probability of fatality**. The three components calculated are (1) the probability that an explosive event will occur at a particular site, (2) the probability of fatality for that event, and (3) the exposure of all persons to a particular event, at a particular site. Once the expected fatalities and probability of fatality are calculated they can be compared to set of decision criteria that must be approved by the Board. The decision criteria are established by studies in two areas, risk experiences and regulatory standards. Risk experiences are the actual average rate of death for various experiences in the population. Examples of these are heart attack, homicide, car accidents, natural disasters, poisoning, etc. The second area studied is regulatory standards which is the maximum annual risk potential allowed for a single individual within other hazardous occupations such as hazardous material storage, nuclear and chemical facilities, and electrical production plants. In short, a number of factors and variables surrounding a particular potential explosive site (PES) and set of conditions are calculated to get the expectation and maximum probability of fatality which is then compared to a set of established criteria to determine whether the risk can be accepted. Thus, operations are permitted within certain risk levels.⁵¹

The risk-based approach to explosives safety essentially provides a quantitative value for risk. Once risk is quantified, absolute safety criteria can be established resulting in an invaluable tool for decision making.

On 9 December 1999, after two and a half years of work by the Risk-Based Explosives Safety Criteria Team, the Department of Defense Explosives Safety Board voted to implement the Risk-Based Explosives Safety Criteria on a two-year trial basis. The implementation of the risk-based approach to explosives safety is a significant step forward for the U.S. Military and it will surely prove to enhance the effectiveness of ordnance logistics. It will also allow a number of existing waivers and exemptions to be removed because of the new criteria. However, this milestone of implementation does not mark the end of work for the Risk-Based Explosives Safety Criteria Team. The initial implementation of this new criterion falls well short of the potential effectiveness of the risk-based system.

The risk-based set of criteria that was approved for trial implementation contains a number of limitations. The risk-based computer model does not include data for vehicles, ships or ports, and the storage consideration is limited to 500,000 pounds NEW. Unfortunately, operational ordnance logistics deals more with the dynamics of transport and flow to and throughout a theater of operations than with static storage. The limitations of the current risk-based model prevent the use of this new tool in the areas of explosive safety that will best enhance ordnance logistics and combat readiness.⁵²

CONCLUSIONS AND RECOMMENDATIONS

The Department of Defense Explosives Safety Program and *DOD Ammunition and Explosives Safety Standards* have contributed greatly to the enhancement of ordnance logistics and ultimately, combat readiness. This monograph has examined history and evolution of explosives safety and the Department of Defense Explosives Safety Board and how the development of the consequence-based *Standard* has enhanced ordnance logistics in the U.S. Military. Also examined was risk management and a risk-based philosophy for maintaining explosives safety in a military environment and its potential impact on logistics.

The consequence-based approach assumes that an explosive incident will take place, determines the distance to which the explosive effects will be felt and then sets exclusion area criteria on that basis. Risk-based criteria calculates the probability of an incident taking into account variable factors like improvements in the sensitivity of the ordnance and relative safety of the operation that is being conducted.

Study and comparison of consequence-based versus risk-based explosives safety approaches leads to the creation of a complex but critically important dilemma that must be considered. This dilemma is complex because it seemingly involves balancing safety and lives against cost. Explosives safety is an area where a single accident can kill hundreds, yet, it asks the question, how much safety is enough? The dilemma is important because the post Cold War U.S. Military is under more pressure than ever to do more with fewer resources. Enhancing the effectiveness of ordnance logistics to assure continued combat readiness is essential. Evidence of this dilemma and its potential impact was discovered during two separate wargames in the past five years. Joint

Ordnance Wargame, JORDWAR-97, and the Focused Logistics Wargame 2010, conducted in October 1999, both contained findings and recommendations vis-à-vis the challenge of flexible ordnance logistics in a downsizing environment, balanced with the current explosives safety requirements of the *Standard*.⁵³

Beyond wargames there were a number of events and situations that highlighted the cause for the consideration of a different explosives safety approach. A situation where the *Standard* had an adverse effect on logistics developed at Naval Weapons Station Concord in California. One of the results of the massive downsizing of the US Armed Forces beginning in 1990 was a significant reductions in the requirement for transshipment of all types of conventional ordnance. As a consequence, workload at weapons stations and facilities dropped off to the point where substantial cutbacks, reductions in force, or even closures were required. One alternative for weapons transshipment facilities was to seek other types of military workload to augment the existing ordnance work.

In Northern California, the closure of the Oakland Army Base, a major transshipment point for Army general cargo, presented an opportunity for Naval Weapons Station Concord, CA., to augment declining ammunition workload with military general cargo. Just closing Concord was not an option. Naval Weapons Station Concord is listed as a “Strategic Port” by the port study prepared by the Military Traffic Management Command (MTMC). Additionally, in a 17 September 1997, memorandum to the Secretary of the Navy, the Secretary of Defense asserted the “need to ensure Concord’s ability to support Major Regional Conflicts.”⁵⁴ However, this opportunity for

significant workload was hampered and almost lost by restrictions imposed by the DDESB *Standard*.

Because of the strict quantity-distance criteria of the *Standard*, general cargo could be handled at Concord but it would limit the amount of ordnance that could be handled simultaneously at the adjacent operations area to only 500,000 pounds compared to its ten million pound net explosive weight (NEW) capability. This reduction in capacity would unacceptably cripple Concord's ordnance logistics capability. The *Standard* allows for requirement waivers but the process is lengthy and tedious. Over a year of Army general cargo work was lost while this waiver was prepared and reviewed by several layers of command.⁵⁵

There exists a valid argument that a year of lost workload is not significant when compared to explosives safety and the protection of lives. However, there is an equally compelling argument that if computed and executed properly, risk-based explosive safety criteria not only provides a safe environment for personnel but also significantly enhances logistical flexibility. In fact, the risk-based criteria, approved for trial by the Board this past December, was used on the Concord 1997 waiver request. When the risk-based criteria was applied, the 500,000 pound NEW, imposed because of quantity-distance limitations, increased to 4.5 million pounds, thus allowing for simultaneous ordnance and general cargo operations. This represents a substantial logistics capability improvement.

Consideration of whether or not the Department of Defense should move beyond the trial implementation and fully adopt risk-based explosives safety leads to two

questions. One, is it safe to do so, and two, is there a benefit to ordnance logistics in peacetime, wartime, or both?

The safety question was answered, in part, by the Department of Defense Explosives Safety Board on 9 December 1999, when by unanimous vote they approved the implementation of risk-based criteria on a trial basis to be used by the Services in conjunction with the current *Standard*. The risk-based effort was well funded and well researched by the Risk-Based Explosives Safety Criteria Team (RBESCT) over a period over of two and a half years.⁵⁶ Another consideration that answers the question of safety is the broad use of risk-based explosives safety by other countries. “In addition, the need to maintain operational flexibility in support of mission readiness without degrading safety makes it even more difficult to satisfy the more ridge deterministic criteria. A risk-based approach for explosives safety, already successfully used by several nations may prove out as the approach for the next generation.”⁵⁷ Additionally, the Swiss Military and Government have been using a risk-based approach to explosive safety since approximately 1975, and it is also being used in the United Kingdom and Australia.⁵⁸

The second question concerning whether there is benefit in the risk-based approach to explosive safety was examined by the Swiss example of the ammunition manufacturing and adjacent storage facilities in section IV. Even more pertinent, the application of the risk-based criteria at Naval Weapons Station Concord clearly illustrates the significant benefits to operational logistics that the risk-based approach has compared to the current consequence-based *Standards*.

Joint Pub 4-0 outlines seven principles of logistics. Three of those principles, responsiveness, economy, and flexibility are prime examples of the advantages the U.S.

Military will gain once the risk-based criteria are fully adopted. Responsiveness is “the right support in the right place at the right time.” Economy is the “provision of support at the least cost.” And, flexibility is “the ability to adapt logistic structures and procedures to changing situations, missions, and concepts of operation.” The risk-based approach to explosives safety embodies all these principles.⁵⁹

Risk-based explosive safety criteria will enhance the principles of operational logistics only if its potential benefits are pursued. Risk-based explosive safety was approved for the Service’s use on a trial basis; however, aggressive action is needed in three areas to ensure its benefits and potentials are realized. First, the Services must not turn back. There are opponents to risk-based explosive safety that believe it is being developed primarily for saving money. There is no question there are cost benefits that can be realized; however, these benefits are consequential to the enhancements to ordnance logistics and combat readiness. Second, the Department of Defense, using the Department of Defense Explosives Safety Board as a conduit for monitoring, must ensure that the Services are correctly using the risk-based criteria during the trial period. The trial data and documentation must be complete and verifiable so that the final implementation is not delayed. Finally, The Risk-Based Explosive Safety Criteria Team (RBESCT) must aggressively work toward completing computation and analysis for the remaining data areas that limit application of the risk-based criteria for all elements of ordnance logistics. Risk data for vehicles, ships, multiple story buildings, and port piers need to be computed and included in the computer model. Additionally the 500,000 pounds net explosive weight (NEW) limitation currently imposed for single storage area must be increased.⁶⁰ The primary advantage of risk-based criteria is the flexibility that it

brings to operation ordnance logistics and eliminating these limitations will significantly enhance that flexibility.

“If the risk-based criteria approach is adopted in lieu of the deterministic criteria (default quantity-distance criteria) approach, the change will have a profound effect on the way the DDESB conducts its business.”⁶¹ This statement by a previous Chairman of the Department of Defense Explosives Safety Board is true enough; however, the profound effect that the risk-based philosophy has goes well beyond the conduct of Board business. Risk-based explosive safety criteria will allow for the continued development and use of explosives in ordnance and ammunition while ensuring public safety. Equally important, the risk-based approach to explosive safety will enhance the future of operational logistics for ordnance and as a result, ensure combat readiness for tomorrow’s United States Armed Forces.

¹ Department of Defense. Explosives Safety Board website: www.acq.osd.mil/ens/esp accessed 10/99. Actual statistics demonstrating the drop in lives lost and property damaged are sited later in this monograph.

² Henry E. Eccles, *Logistics in the National Defense* (Westport, Conn:Greenwood Press Publishers, 1959), 10.

³ Kenneth Macksey, *Technology In War* (New York: Prentice Hall Press, 1986), 7.

⁴ Department of Defense. Explosives Safety Board website: www.acq.osd.mil/ens/esp accessed 10/99.

⁵ Robert L. Allen. *The Port Chicago Mutiny* (New York: Amistad Press Inc., 1993), 56-68. In 1944, although the Armed Forces were only partially integrated. In the Navy, Black sailors were not assigned to shipboard duty but rather assigned ashore. At Port Chicago, Blacks were assigned as stevedores and ammunition handlers. Of the 320 killed in the explosion, 202 were Black sailors. After the explosion at Port Chicago 50 Black seaman refused to go back to work on the piers for fear of additional explosive incidents and were subsequently court martialed. Controversy surrounded the Navy's action and still continues today.

⁶ The Secretary of Defense, *DoD 6055.9-STD, DoD Ammunition and Explosive Safety Standards*, (Washington, D.C. August 1997), 1-3 and Appendix A. Quantity distance is the relationship between the quantity of explosive and the distance of separation for providing defined types of protection.

⁷ Parke Davis, "Explosives and its Effect on Base Planning and Mission," *TIG Brief*, November-December 1995, 10-11.

⁸ Naval Sea Systems Command , SEA 05M. Briefing from the Sensitive Munitions Office. 1999. Sensitivity of munitions refers to the amount of outside influence required to detonate an explosive.

⁹ The Secretary of Defense, *DOD Directive 6055.9, DOD Explosives Safety Board and DOD Component Explosives Safety Responsibilities*, (Washington, D.C., July 29, 1996) 2-1.

¹⁰ Joint Chiefs of Staff, *Joint Pub 1-02, Dictionary of Military and Associated Terms* (Washington, D.C., June 1998), 164,299.

¹¹ *Ibid.*, 264.

¹² Naval Ordnance Center. Report on the Independent Review, Analysis, and Recommendations of JORDWAR-97. February 1998. This definition originated at the Naval Ordnance Center and was generally accepted and used in several presentations associated with the Joint Ordnance Wargame held in May 1997.

¹³ The Secretary of Defense, *DoD 6055.9-STD*, Appendix A, 4,6.

¹⁴ John E. Dolan and Stanley S. Langer, eds. *Explosives in the Service of Man* (Chambridge, U.K.: Thomas Graham House, 1997), 17.

¹⁵ *Ibid.*, 17and 18. Mining throughout Europe was the main non-military application of explosives for the next several hundred years.

¹⁶ Ibid., 18.

¹⁷ Kenneth Macksey. *Technology in War* (New York: Prentice Hall Press), 10.

¹⁸ Arthur Pine VanGelder and Hugo Schlatter, *History of the Explosives Industry in America* (New York: Columbia University Press, 1927) 65 and 1083.

¹⁹ Dolan, *Explosives in the Service of Man*, 19.

²⁰ Ibid., 35- 39.

²¹ Richard W. Wright and Dr. Jerry M. Ward, "DDESB – Evolution for Meeting the Requirements of the 21st Century," An unpublished paper written in by the then Chairman of DDESB Colonel Wright, USA and Dr. Ward of the DDESB Secretariat.

²² Henry E. Eccles, *Logistics in the National Defense* (Westport, Conn: Greenwood Press Publishers, 1959), 10 and 20.

²³ Joint Chiefs of Staff, *Joint Vision 2010*, (Joint Staff, Washington, D.C., 1996), 19.

²⁴ Department of the Navy, *Navy Doctrine Publication 4, Naval Logistics*, (Washington, D.C., 1995), 67.

²⁵ Eccles, *Logistics in the National Defense*, 2. Quote is from R. G. Ruppenthal, *Logistics Support of the Armies*, (Office of the Chief of Military History, Department of the Army, Washington, D.C., 1953), 583.

²⁶ Desmond Saunders-Newton, "Adaptive Battlefield Ammunition Distribution: The Role of Systematic Adaptation in Dynamic Environments," (UMI Dissertation Services, 1993), 4-5.

²⁷ Scott E. Wohlenhaus, "Ammunition Safety, Not Just Peacetime Rules," *Ordnance*, January 1992, 42-43. and Thomas M Tobin and Robert A Rossi, "Safeload: Improving Ammo Safety," *Army Logistician*, November-December 1992, 2.

²⁸ Nile James, Executive Director, Naval Weapons Station Concord, CA. Summary from a series of e-mails dated 12-16 March 2000.

²⁹ Joseph M. Heiser Jr. *Logistic Support, Vietnam Studies* (Washington, D.C.: Department of the Army, 1974), 126-128.

³⁰ Nile James, e-mail dated 16 March 2000.

³¹ J. Howard McGrath, letter from the Attorney General to Secretary of the Navy dated 27 October 1949. Quoted excerpt from Act of December 22, 1927, (45 Stat. 2, 35). Letter contained in the historical files at Department of Defense Explosives Safety Board.

³² Department of Defense Explosives Safety Board. Board historical files, Memorandum For: The Joint Army-Navy Ammunition Storage Board dated 9 July 1946. Historical files at DDESB. Point of contact at DDESB for historical record and information is MR James Drake, DDESB-KO. The American Table of Distances was one of the earliest quantity-distance tables used in the U.S. and was a result from studies throughout the world since 1863.

³³ Ibid., 2.

³⁴ Rick Adams, "July 17, 1944." *Explosive Safety*, Vol 4, March 1994, 3-5. Most consider the December 6, 1917 explosion of the *Mount Blanc*, in Halifax Harbor to be the worst. That explosion involved 5,200,000 pounds NEW and resulted in 1,800 and 8,000 injuries.

³⁵ Department of Defense Explosives Safety Board. Board history files, Memorandum For: The Joint Army-Navy Ammunition Storage Board dated 9 July 1946, 8-9. Additional information from: Wright and Ward, "DDESB – Evolution For Meeting the Requirements of the 21st Century," 2-3.

³⁶ United States Code, Title X, Section 172, Ammunition Storage Board.

³⁷ Joseph M. Heiser, Jr., *Logistic Support, Vietnam Studies* (Washington, D.C.: Department of the Army, 1974) 262.

³⁸ The Secretary of Defense, *DOD 6055.9-STD*, 1.

³⁹ Explosives safety doctrine for the Services are: Navy and Marine Corps: Naval Sea Systems Command, OP4 and OP5 Ammunition and Explosives Safety Regulations, (Afloat and Ashore respectfully); Army: Pamphlet 385-64, Ammunition and Safety Standards; Air Force: AF Manual 91-201, Explosives Safety Standards.

⁴⁰ The Secretary of Defense, *DOD 6055.9-STD*, Chap 3, pp.1. Some examples of Hazard Divisions are: mass-detonating 1.1 (high explosive), non-mass detonating fragment producing 1.2 (some grenades and warheads), mass fire 1.3 (pyrotechnics), and moderate fire-no blast 1.4 (small arms ammunition).

⁴¹ Ibid., Chapter 2, pp. 1-8.

⁴² Discussion and reference of this incident is in Section III, pp. 17.

⁴³ Department of the Navy, Naval Ordnance Center, "Investigation into the Circumstances Surrounding the Explosion That Occurred 01August 1994, at Naval Surface Warfare Center, Indian Head Division, Indian Head, Maryland." Serial N00/460, 7 OCT 1994.

⁴⁴ Department of Defense Explosives Safety Board. Introductory briefing conducted December 1999, to the Board by the Risk Based Explosives Safety Criteria Team (RBESCT). DDESB files.

⁴⁵ Department of the Army, *FM 100-14, Risk Management*, (Washington, D.C., April 1998), 1-1.

⁴⁶ Andreas F. Biezen, "Swiss Safety Concept, Regulations and Organization in the Field of Military Explosives Safety." Biezen, Kummer & Partner LTD, Consulting Engineers. Paper presented at the 5th International Symposium on Explosive Technology, 12-14 October 1994. Para. 1.

⁴⁷ Ibid., Para. 3.2-3.5.

⁴⁸ Ibid., Para. 4.1.

⁴⁹ Department of Defense Explosives Safety Board. Board minutes and history files. Chapter One of *DOD 6055.9STD* contains the procedures for obtaining waivers and exemptions. In 1995, the Office of the Deputy Secretary of Defense for Environmental Security (DUSD (ES)), directed the Services to reduce, wherever possible, the numbers of waivers and exemptions in effect.

⁵⁰ Tobin and Rossi, "Safeload: Improving Ammo Safety," 2-3. The Department of the Navy's IM program is governed by OPNAVINST 8010.13C. Test requirements for the IM program are detailed in military standard, MIL-STD-2105B.

⁵¹ Department of Defense Explosives Safety Board. Board minutes and history files. Compiled from a Board briefing on Risk-Based Explosive Safety, conducted on 9 December 1999.

⁵² Ibid., The limitations referred to were addressed by the Risk-Based Explosives Safety Criteria Team. The impact of the limitations are the opinion of the author.

⁵³ Naval Ordnance Center. Report, Analysis and Recommendations of JORDWAR-97, conducted May 1997. Issue number IC-05. Focused Logistics Wargame (FLOW) 2010, conducted October 1999. Executive Summary pp. 7 and Pillar Matrix, pp. 49.

⁵⁴ Military Traffic Management Command, Transportation Engineering Agency. Website www.tea.army.mil accessed 11 FEB 1900. The SECDEF memorandum was a follow-up to the 1997 Program Budget Decision (PBD-407).

⁵⁵ Nile James, Executive Director, Naval Weapons Station Concord, CA. Interviewed by author by phone in July 1999.

⁵⁶ Discussion of the Risk-Based Explosives Safety Criteria Team (RBESCT) and the evolution of the Criteria is contained section IV, pp.32-34.

⁵⁷ Wright and Ward, "DDESB – Evolution for meeting the Requirements of the 21st Century." 11.

⁵⁸ Bienz, "Swiss Safety Concept, Regulations and Organization in the Field of Military Explosives Safety." Para. 2.

⁵⁹ Joint Chiefs of Staff, *Joint Pub 4-0, Doctrine for Logistics Support of Joint Operations*, Joint Staff, Washington, D.C., 1995) II-1 and II-2.

⁶⁰ Department of Defense Explosives Safety Board. Discussion concerning the limitations that exist in the current risk-based explosives safety criteria trial model is contained in section IV, pp. 34.

⁶¹ Wright and Ward, DDESB – Evolution for meeting the Requirements of the 21st Century." 11.

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